The Reservoir Characteristics and Formation Mechanism of Ordovician Fracture Reservoirs in Yingmai2 Area

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***Abstract*- YingMai2 area, with typical fracture reservoirs of very low matrix porosity and permeability, is located in an old buried mountain tectonic belt where faults and fractures are well developed. The main storage spaces are of secondary porosity, such as tectonic fractures and pores, dissolved vugs, holes and cracks. The fracture reservoirs in YingMai2 area are controlled by two factors, which are tectonic movements of faults and expansion dissolution along fractures. The middle Caledonian, late Caledonian, late Hercynian and late Hercynian-Indosinian faults systems are the main formation mechanisms of the fracture reservoirs in YingMai2 area. The fracture reservoirs are also influenced by expansion dissolution along fractures.**

KeyWords-YingMai2 Area; Fracture Reservoirs; Reservoir Characteristics; Formation Mechanism

I INTRODUCTION

Yingmai2 area, an Ordovician carbonate cave-fracture oil and gas field, is located in No. 2 buried mountain belt, north Tarim Basin. Fractures are very rich in Yingmai2 area. Fractures can be oil and gas storage spaces, and can enhance the reservoir connectivity. There is an important relationship between the development of fractures and hydrocarbon migration and accumulation. It is extremely important to research the reservoir characteristics and formation mechanism of fracture reservoirs in Yingmaili Area

II REGIONAL TECTONIC CHARACTERISTICS

Yingmaili area, including Yingmaili low uplift and western Luntai uplift, is located in the western end of North Tarim uplift, Tarim basin. It is a southward dipping nose-like uplift surrounded by sags, Kuche depression in the north, Halahatang sag in the east, Manjiaer sag of North depression in the south, and Awati sag in the west[1, 2](Figure 1).

Faults are very rich in Yingmai2 area, mainly trending NE, NW, and NNW. The fault type includes normal faults, reverse faults, and strike-slip faults, combined with various patterns [3].

The drilled Ordovician formations in Yingmai2 area from top to bottom are Sangtamu formation, Lianglitage formation, Tumuxiuke formation, Yijianfang formation, and Yingshan formation. Ordovician strata are overlain unconformably by Silurian strata [4].

III RESERVOIR CHARACTERISTICS

A. Characteristics of Reservoir Petrology

In Yingmai2 area, upper Ordovician Lianglitage formation reservoir rocks are mainly brown gray and brown nodular limestone; Tumuxiuke formation algae bonded rocks, bioclastic micritic limestone, brecciated micritic limestones, nodular limestone; Yijianfang formation sparry calcarenites, sparry gravel limestone, sparry oolitic limestone, sparry bioclastic limestone, micritic grain limestone; Yingshan formation micritic limestone with calcarenites.

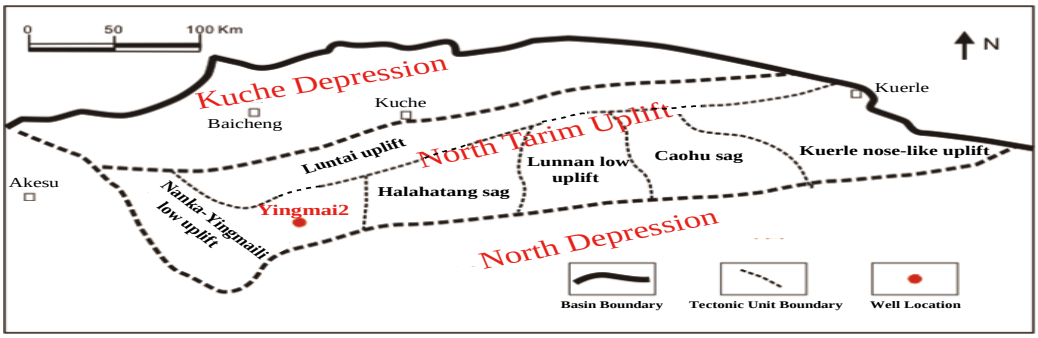

Fig.1 Regional location map

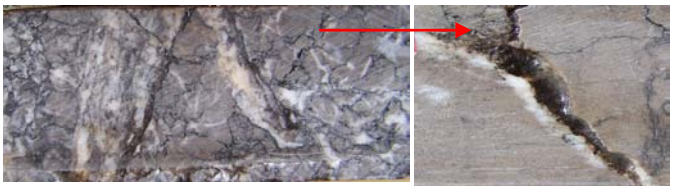

Fig. 3a Well Yingmai201, 20 meters wide large fault fracture zone; unfilled fracture full of oil

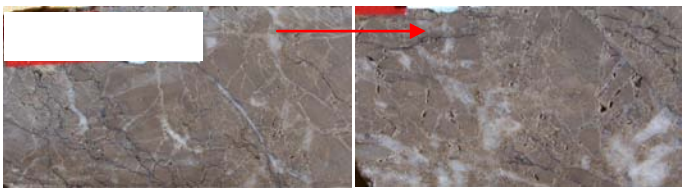

Fig. 3b Well Yingmai3, Micro-cracks developed

Fig.3c Well Yingmai2-4, unfilled and half-filled high angle fractures

B. Characteristics of Reservoir Physical Properties

According to the statistics from 521 measured reservoir properties, the average porosity of Ordovician carbonate reservoir is 1.17%, and the average permeability is $0.51\times 10^{-3}\mu m^2$.

The small rock samples measured core porosity is very low, which indicates that the matrix porosity of Ordovician carbonate reservoir in Yingmai2 area is very poor [5]. Intragranular solution pores and intergranular pores are rarely seen in casting thin sections. Cracks with residual porosity exit in particular layers.

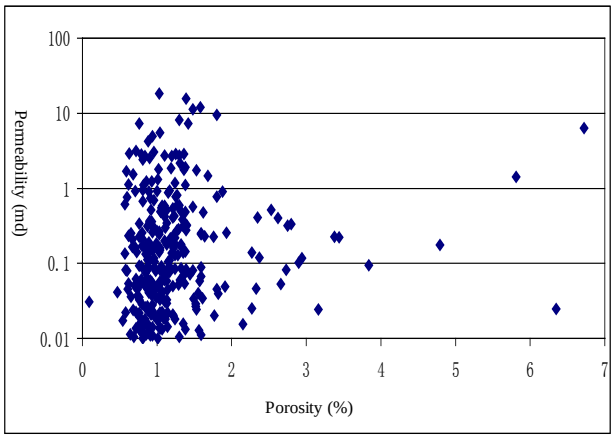

Fig. 2 Correlation analysis of porosity and permeability for Ordovician carbonate reservoir in Yingmai2 area

The correlation analysis of the Ordovician carbonate reservoir porosity and permeability shows that porosity is not correlated with permeability (Figure 2). It is concluded that the storage space and flow channels are micro-pores and micro-cracks, and the type of reservoir space can be classified into fracture type and dissolution vug-fracture type, with very low matrix porosity and permeability and extremely poor reservoir physical properties.

C. Characteristics of Fault and Fractures

Most of the fractures of the fissure reservoirs in Yingmai2 area are structural fractures associated with faults, and next dissolved cracks. Generally, the reservoir property of this type of reservoir is poor. The mercury injection properties data from small core samples inaccurately reflect the characteristics of faults and fractures. Identification of faults and fractures always relies on imaging logging data and cores.

There is a twenty-meter wide large fault fracture zone developed in the Ordovician Yingshan formation limestone stratum, which has been drilled by well Yingmai201. Fault breccias are very rich. Most structural fractures and expansion dissolution fissures are filled by calcite. There are also calcite intergranular pores left in some fractures. Some structural fractures in Ordovician Yijianfang formation and Yingshan formation of well Yingmai201 are half-filled by calcite, and are otherwise full of oil (Figure 3a).

Unfilled and half-filled micro-cracks are very developed in the cores drilled from Ordovician Yingshan formation by well Yingmai3 (Figure 3b). The fracture zone drilled by well Yingmai2-4 can be identified by imaging logging data. Images show that the high angle fractures are rich in the upper Yingshan formation (Figure 3c). The fractures are unfilled or half-filled.

IV THE FORMATION MECHANISM OF FRACTURE RESERVOIRS

The formation and preservation of carbonate reservoir related closely with the evolution of secondary vugs, fissures and caves, are mainly controlled by the paleotectonic evolution, the development of faults and fractures, and

diagenesis. The formation and development of Ordovician carbonate fracture reservoir in Yingmai2 area are primarily dominated by the tectonic movements of faults and the expansion dissolution along fractures.

A. Tectonic Movements of Faults

Fault system is an important factor which influences the development of carbonate fracture reservoir. And tectonic movements of faults are important mechanisms for the formation of fractures. With the analysis on the fractures in this area, it's proved that the development of fractures is associated closely with the characteristics of faults.

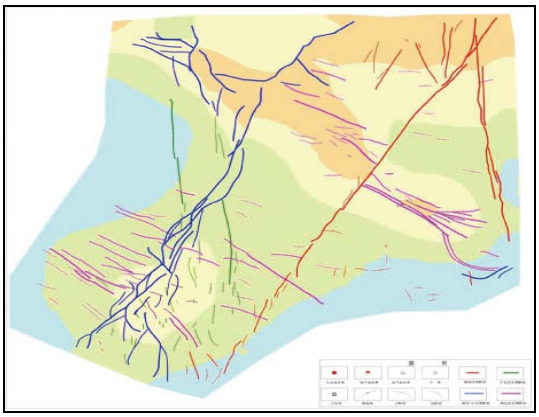

Fig. 4 The outline map of faults in Yingmaili1-2 area

The faults in Yingmaili area are mainly developed in middle Caledonian, late Caledonian, late Hercynian and late Hercynian-Indosinian. Middle Caledonian faults are represented in green, late Caledonian purple, late Hercynian red, and late Hercynian-Indosinian blue (Figure 4) [3].

According to the fracture prediction map, and the imaging logging data of Yingmai2 area, it's concluded that there are good matching relations between the nearly north-south distributed fractures and middle Caledonian faults trending nearly north-south, and between the fractures trending nearly NNW and late Caledonian faults [4]. So it's believed that the fractures in this area are dominated by middle Caledonian faults and late Caledonian faults.

The faults superimposed on a fracture prediction map show that: (1) the fractures in east of Yingmai2 area are dominated by middle Caledonian faults, which are rich there, however, late Caledonian faults are not so developed there; (2) the fractures are mainly NNW distributed in west of Yingmai2 area, where late Caledonian faults are developed.

There is a close relationship between the formation and distribution of dissolution fissure-vug reservoirs and the distribution of regional faults and fractures. The permeability and connectivity of rocks are enhanced by fractures, which also contribute to the activities of pore water and groundwater, and the development of dissolution fissures and vugs. Then a system consisting of vugs, fissures, and caves is formed. The carbonate fracture zone is often the area where reservoirs are most developed, even the region where hydrocarbon most easily accumulated.

B. Expansion Dissolution along Fractures

In Yingmai2 area, dissolution along fractures is a very obvious phenomenon, especially along high angle fractures. The fractures are partly filled by Calcite, and partly dissolved which presents isolated vugs on cores and FMI (imaging logging) images (Figure 5). The dissolution is related closely with atmogenic fresh water.

Fig. 5 The characteristic of expansion dissolution along fractures
(Left up, Well Yingmai 201; Left down, Well Yingmai 206; Right, FMI of Well Yingmai 206)

V CONCLUSIONS

Porosity and permeability of the matrix are extremely low in Ordovician carbonate reservoir of Yingmai2 area. The storage and flow spaces are main structural fractures, dissolved vugs, holes, and cracks.

Faults belts and fractures are rich in this area. Fractures are mainly high-angle, though there are also some low-angle fractures and horizontal ones. Fractures are partly filled by Calcite. The vugs dissolved along fractures are developed, with good hydrocarbon evidence.

Faults in Yingmaili2 area developed mainly in middle Caledonian eras, late Caledonian eras, late Hercynian eras and late Hercynian-Indosinian eras. And the fractures in this area are dominated by the faults formed in middle Caledonian and late Caledonian. The plenty of fractures associated with the superimposed multi-stage fault system are the main formation

mechanism of the fracture reservoir in this area, and the fractures also create favorable condition for dissolution.

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